BIOPSYCH NOTES

TRANSCRANIAL MAGNETIC STIMULATION

WHAT IS TMS?

- TMS is a non-invasive technique to create virtual cortical lesions
- Patients with real lesions allow us to study what they can no longer do
- Temporary and reversible, localised lesions allow for a better understanding of the function of specific brain regions
- Why not always use patients?
    - There might not be enough patients with circumscribed lesions to study all cognitive areas
    - Lesions in single, specialised areas are rare
    - Recovery and brain plasticity might compensate for lesions over time
- Examples of loss of function with lesions:
    - Phineas Gage – iron rod pierced his head and frontal cortex, causing severe personality change
    - HM – removing most of his hippocampus, para-hippocampal gyrus and amygdala lead to severe anterograde amnesia
    - Lesions in Broca's and Wernicke's areas are linked to impairments of speech production and language comprehension respectively

HOW DOES TMS WORK?

- Barker, Jalinous & Freestone (1985) developed the current TMS technique
- TMS can be applied externally, using a coil in the scalp
- Coil produces a rapidly changing magnetic field to induce electrical currents in the brain
- These currents depolarise neurons in a small, circumscribed area of the cortex, causing them to fire randomly and increasing the level of 'neural noise', which masks the neurons that are firing correctly
- In order to create the current pulse that is required to generate the magnetic field, a capacitor is charged and then suddenly discharged
- In order to create a magnetic field strong enough for stimulation, very fast loading times and short durations are required
- This process can be modified to create a fast sequence of pulses (as in rTMS)

Types of Coils:

- Single loop coil or figure 8 coil (most common)
- Difference between the coils is in the type and precision of the stimulation that each can create
- Figure 8 coil generates a magnetic field in the opposite direction, thereby generating offset current loops, that also circulate in opposite directions
- Where the 2 current loops meet, there is stimulation – results in a more focused area of the cortex being stimulated
- The advantage is that the researcher has a very clear idea what area of the cortex is being affected

DIFFERENT WAYS TO USE TMS

Injection of Neural Noise Approach

- Uses single-pulse TMS to disrupt cognitive processing
- Provides a way to demonstrate/testing causality: if a single-pulse TMS pulse to a specific region disrupts a cognitive function, there is a causal involvement
- Introducing neural noise can interfere with the cognitive process of interest at exactly the time which during which the region is required
- Regions don't stop working completely, but neural noise interrupts normal functioning

Study:

- Researchers used 3 alphabetic letters as stimuli, presented under difficult viewing conditions
- TMS was applied ~2cm above the inion, over the visual cortex
- Effects on letter perception when varying the interval between visual stimulation and TMS was investigated
- During a critical period (40-120ms), TMS affected detection performance
- When shifting the TMS site from L to R hemispheres, perception of letters in the contralateral visual field was impaired
- When shifting the TMS site up, detection of letters at the bottom of the screen was impaired

Study:

- Investigated whether a 'visual mask' can itself be masked' using single-pulse TMS, thereby 'unmasking' the stimulus
- Backwards masks are presented after the stimulus and are used to suppress perception of the briefly presented visual stimulus
- TMS can be used to disrupt processing of the stimuli, and therefore could potentially also disrupt processing of the mask, thereby preventing the suppression of the initial stimulus
- Without TMS, detection rate of the stimulus is 37%, but with TMS following the mask, detection rate increased to 90%
- Unmasking was found between 60-140ms after the mask

Virtual Lesion Approach

- Uses rTMS (repetitive TMS) to interrupt or enhance cognitive processing
- It's possible to inhibit cognitive functions for a longer period of time by applying rTMS
- It can then be measured whether, and how long for, a specific cognitive task is impaired (usually impairment is slowing instead of loss of function)
- Strict safety guidelines for rTMS

Probing Excitability Approach

- Uses single pulse TMS
- For the motor system, it's possible to test how responsive/excitable the motor cortex is during a cognitive task

- If the motor cortex is required for a cognitive task, then it should already be activated when single-pulse TMS is delivered
- Instead of disrupting cognitive function and measuring performance, the measure of interest ins how strongly the motor cortex reacts to the pulse itself
- Excitability of the M1 is measured by recording the 'motor evoked potentials' (MEPs) using EMG (measures electrical activity of the muscles)
- TMS is applied to a specific area of M1, neurons fire and cause muscle activity in the specific corresponding body part, and the activity of the muscle is recorded in MEPs
- MEPs for each stimulation are measured and compared between experimental conditions

Study:
- Is M1 involved in the mental rotation of objects?
- Mental rotational task was administered and single pulse TMS was applied to the hand region of the M1, and MEP data was collected
- Stimulation of the M1 during mental rotation elicited stronger MEPs compared to a baseline
- Evidence that the M1 is more excitable during mental rotation, indicating that it may already have been activated and is involved in this cognitive process

Study:
- Does the involvement of the M1 in mental rotation depend on strategy?
- It's been suggested that some objects can easily be imagined as being rotated by the hand, while others can't
- However, MEPs were equally high for mental rotation of all stimuli, so strategy probably doesn't play a role

The studies do not answer whether the M1 was only more excitable because adjacent and interconnected regions were activated.

Probing Information Transfer using the Paired Pulse Approach
- Uses 2 pulses delivered in brief succession (one is sub-threshold and the other is supra-threshold)
- How strongly does the first pulse influence the effect of the 2nd?

Study:
- Abnormalities in inhibition in the M1 have been suggested in those with Schizophrenia
- Evidence that the cortical silence period (CSP, a period of suppression of tonic motor activity that follows excitatory activity) is reduced
- Researchers produced the excitatory activity by a 1st TMS stimulus to the left M1, and measured excitability by assessing the effect of a 2nd pulse through MEPs
- Compared to controls, patients with and without medication showed stronger responses to the second pulse

Study:
- Testing whether the primary visual cortex (V1) is necessary for visual awareness
- Is feedback from secondary visual areas to the V1 required to construct awareness?

- V1 and V5 were stimulated at different points in time
- V1 stimulation was sub-threshold and V5 stimulation was supra-threshold
- TMS applied to V1 before V5 caused no effect on seeing moving phosphenes, independent of the delay between pulses
- TMS applied V5 before V1 caused less phosphenes to be perceived or phosphenes did not move
- Indicates that back-projections from V5 to V1 are required for awareness

CLINICAL APPLICATIONS OF TMS

TMS as a treatment option for depression

- 1 hemisphere is stimulated over the prefrontal cortex with the idea that depression is linked to imbalance of prefrontal activity between hemispheres
- Last resort treatment option
- Mixed evidence for effectiveness, but increasingly accepted as an option
- Shown positive results for some patients

TMS is also a potential treatment for other mental disorders.